Impact of 50% Synthesized Iso-Paraffins (SIP) on F-76 Fuel Coalescence

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LIST OF ACRONYMS/ABBREVIATIONS

ASTM ..... American Society for Testing and Materials

DLA ..... Defense Logistics Agency

F-76 ..... USN F-76 Grade Diesel Fuel

FLC ..... Fleet Logistics Center

HEFA ..... Hydroprocessed Esters and Fatty Acids

HRJ-5 ..... Hydroprocessed Renewable Jet Fuels

IAW ..... in accordance with

NCT ..... Navy Coalescence Test

NSTM ..... Naval Ship's Technical Manual

PPM ..... parts per million

SIP ..... Synthesized Iso-Paraffins

DEFINITIONS

Coalescence ..... the ability to shed water from fuel

Dissolved Water ..... water that is in solution with the fuel i.e. at or below the saturation point

Element ..... a separation device comprised of a filter coalescer and separator

Free Water ..... water in a multi-fluid stream which is above the fluid's saturation point (not dissolved water)

Saturation point ..... the total water concentration at which all water present in the fuel is dissolved in the fuel and the further addition of water will result in the presence of free water. The saturation point is heavily dependent on the chemical composition of the fuel and temperature.

Turnover ..... time required to flow the entire volume of fluid in a container, also known as residence time (volume of fuel ÷ volumetric flow rate)

EXECUTIVE SUMMARY

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

An alternative sourced fuel currently under-going qualification testing is a 90/10 blend of petroleum JP-5 and Synthesized Iso-Paraffins (SIP). SIP fuels are made from direct fermentation of sugar into olefinic hydrocarbons. The olefinic hydrocarbons are hydroprocessed to produce an iso-paraffinic hydrocarbon. To represent this class of renewable jet fuel, the Navy received SIP that was a 98% pure branched paraffin with a fifteen carbon chain called 2,6,10 trimethyldodecane or farnesane.

The 50/50 F-76/SIP fuel blend's ability to coalesce free water was evaluated by performing a Navy Coalescence Test (NCT). The NCT is a level II fit-for-purpose test which uses a specially manufactured scaled down filter/coalescer and separator to simulate the performance of a full-scale filter separator system. This test is designed to predict the performance of new additives and fuels on filter separator systems currently in use by the fleet.

After 80 hours of testing it was concluded that 50/50 petroleum F-76/SIP meets the acceptable performance criteria and that 50/50 F-76/SIP progress to full-scale single element testing. In the interim, 50/50 F-76/SIP qualification testing should also continue.

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1.0 BACKGROUND

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

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Chapter 541 of the Naval Ship's Technical Manual (NSTM) specifies a free water limit of 40 ppm in F-76 grade diesel fuel. Excessive free water in fuel systems will facilitate the growth of microbial organisms and negatively impact engine performance. Therefore centrifugal purifiers and filter coalescers are commonly used to decrease the concentration of free water to acceptable limits. The Navy Coalescence Test (NCT) is a level II fit-for-purpose test in the Navy's qualification protocol designed to simulate a full-scale filter separator system so that a fuel's ability to coalesce water can be evaluated on a small-scale.

2.0 OBJECTIVE

The objective of this test was to determine the effects of 50% SIP (by vol.) on the coalescence properties of F-76 by comparing free water levels upstream and downstream of a scaled down filter coalescer and separator filtration system.

3.0 APPROACH

3.1 Test Overview

Testing was conducted in accordance with (IAW) NCT Standard Work Package SWP44FL-003. The test is comprised of saturating dry fuel with water (via wet N_2 sparging),

injecting 250 ± 50 ppm of free water upstream of the filter coalescer and separator element, and removing the water via the element. The total water concentration in the fuel is measured at each of these three locations per American Society for Testing and Materials (ASTM) procedure ASTM D6304. Three samples from the inlet and outlet of the filter separator capsule and one sample of water saturated fuel are measured each hour. By measuring and graphing the results of the water levels at these three locations, the effects on coalescence can be determined. When coalescence is unaffected, the water levels in the saturated fuel and at the outlet of the element are close in value and give consistent results. When coalescence is compromised, the water levels at the inlet and outlet of the element are closer. Differential pressure across the coalescer is also recorded to ensure the differential pressure does not exceed 15 psi at which point filter coalescer and separator performance is compromised. The standard test duration is 80 hours. A flow schematic for the NCT rig is shown in Figure 1.

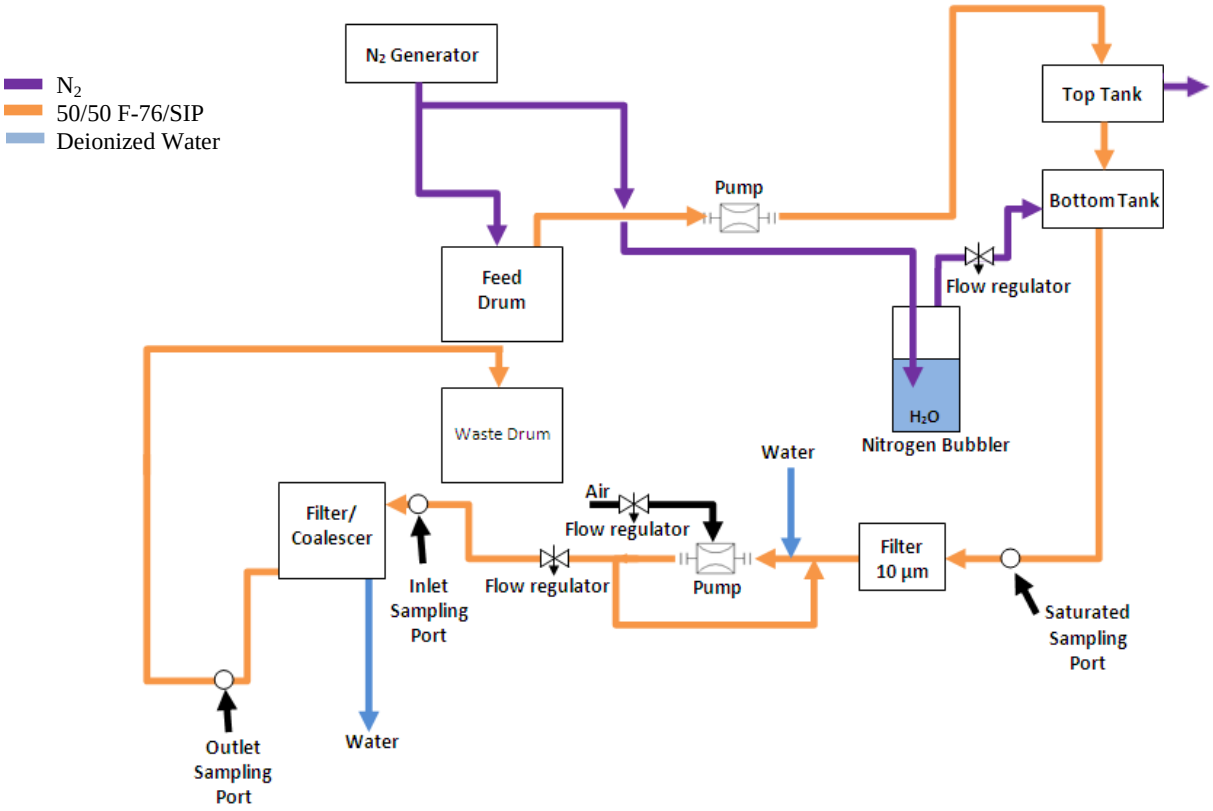

Figure 1: NCT Flow Schematic

3.2 Test Fuel

The F-76 was acquired from Fleet Logistics Center (FLC) Puget Sound. The SIP was acquired directly from the manufacturer, Amyris. Prior to blending the two components, laboratory tests were completed at NAS Patuxent River's Naval Fuels Laboratory to ensure the F-76 met all requirements specified in MIL-DTL-16884M. The two components were then blended at a 50/50 by volume ratio and tested to ensure conformance to MIL-DTL-16884M. To prevent sediment from clogging the lines of the NCT rig, the blended fuel was recirculated

through a series of 0.5 micron (nominal) filters and coalescers until the particulate content of the test fuel was <0.5 mg/L.

3.3 Acceptance Criteria

In order to successfully pass the NCT, the difference between the total water concentration of the saturated fuel and the fuel leaving the test element (i.e. free water) must be less than 100 ppm. If this criterion is not met for four consecutive hours, the test will be reported as a failure. The 100 ppm limit has been chosen because it allows for variations in the fuel sample, as well as system disturbances such as excess water injection and incomplete saturation due to fluctuations in nitrogen pressure. The differential pressure across the capsule which houses the filter and separator shall not exceed 15 psi at any point during the test. If the differential pressure exceeds 15 psi the fuel fails the NCT.

4.0 DISCUSSION

The average total water concentration of the saturated fuel stream and the filter separator inlet and outlet fuel streams can be found in Figures 2 and 3. Figure 3 excludes the inlet total water measurements to better illustrate the differences between the saturated and outlet water concentrations. Times when the outlet water concentrations are below the saturation concentration are indicative of periods of excessive water saturation since filter coalescers are only able to remove free water. For the 15 test hours excessive water saturation occurred, the water saturation point is estimated as the average of the 65 test hours oversaturation did not occur which was calculated to be 63 ppm total water. Since the fuel temperature varied between 64°F and 71°F throughout the evaluation period, 63 ppm is a reasonable estimate of the actual water saturation concentration.

The average amount of free water injected in the saturated fuel stream and coalesced by the filter separator at each test hour can be seen in Figure 4. For the 15 test hours that over saturation of the test fuel occurred, the estimated saturation point was used to calculate the amount of free water injected into the fuel stream. Since the amount of free water coalesced is the difference between the inlet and outlet measurements, oversaturation of the test fuel does not directly affect the amount of free water coalesced. On average, 297 ppm free water was injected into the test fuel.

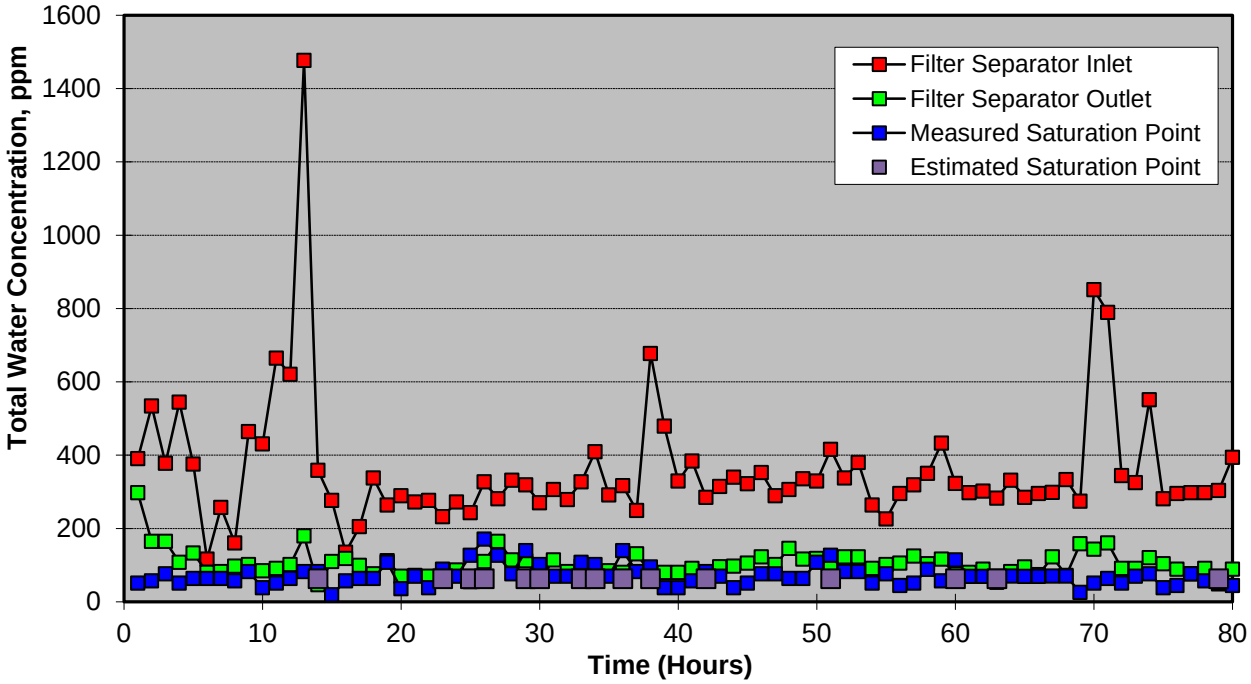

Figure 2: Average Total Water Concentration: Saturated Fuel Stream, Filter Separator Influent and Effluent

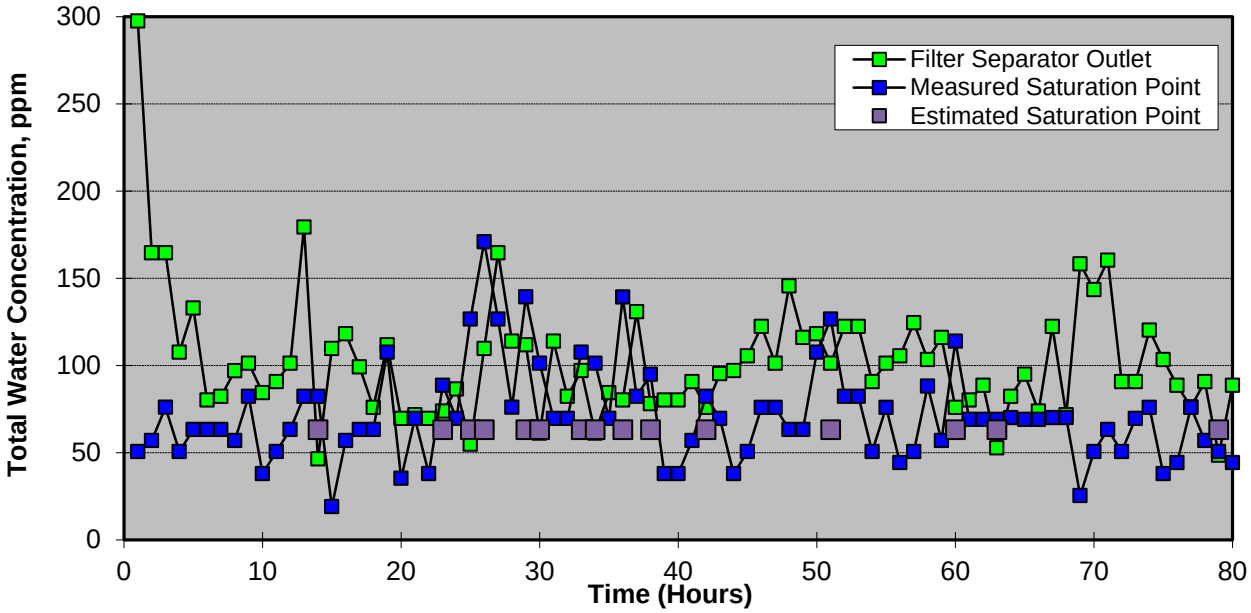

Figure 3: Average Total Water Concentration: Filter Separator Effluent and Saturated Fuel Stream

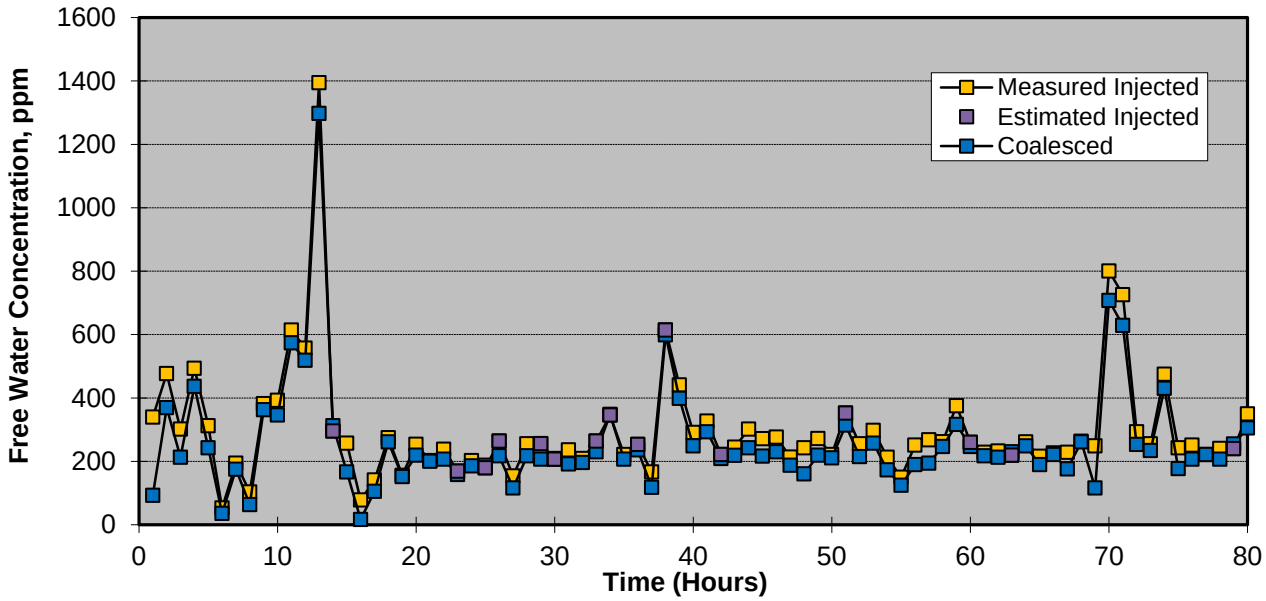

Figure 4: Injected and Coalesced Water

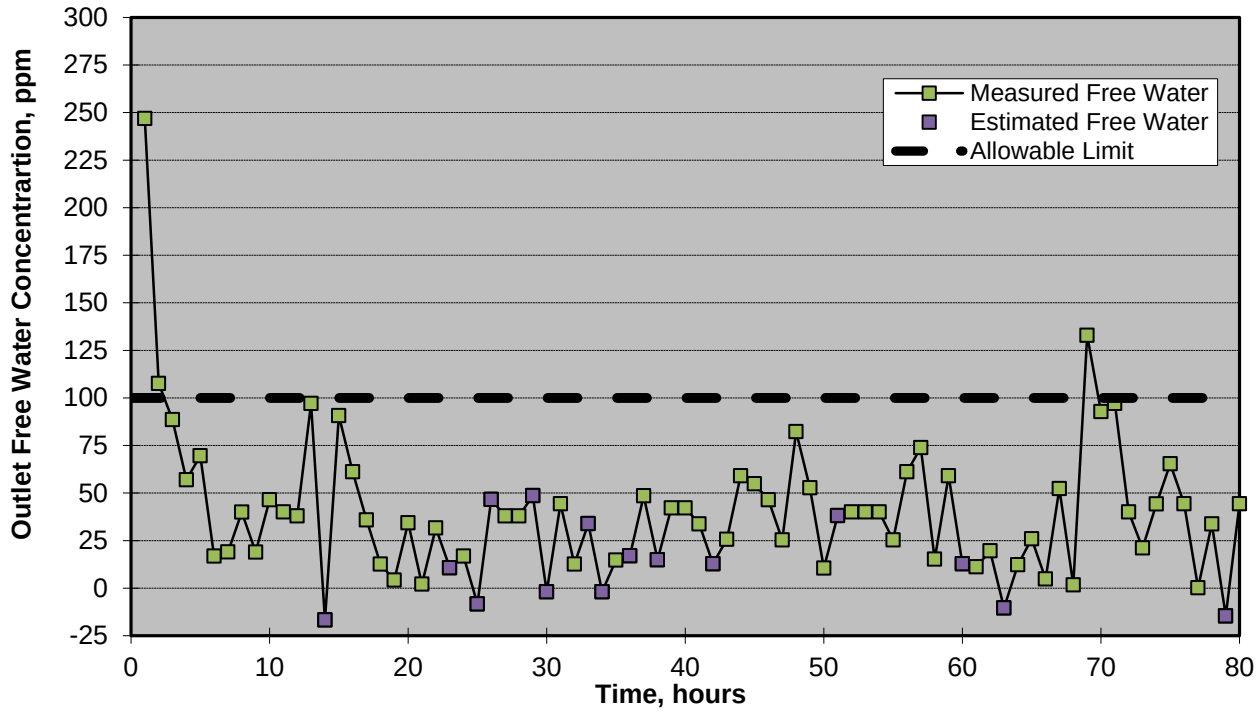

Figure 5: Free Water Concentration at Outlet of Test Element

As can be seen in Figure 5, free water concentrations >100 ppm were measured at only three test hours. The average free water concentration measured at the outlet of the filter separator was 39 ppm (std dev= 38 ppm). At no point during the test did the differential pressure across the filter separator capsule exceed 3 psi. Therefore the 50/50 F-76/SIP fuel blend satisfactorily met the NCT acceptance criteria.

5.0 CONCLUSIONS

The 50/50 F-76/SIP fuel blend met all of the NCT requirements. Based on this analysis, SIP does not adversely affect F-76 water coalescence when blended at a ratio of 50% F-76 and 50% SIP by volume.

6.0 RECOMMENDATIONS

It is recommended that 50/50 petroleum F-76/SIP blends continue qualification testing. Additionally, it is recommended that a 50/50 F-76/SIP blend be tested on a full-scale single filter element system to ensure compatibility with current filtration infrastructure.

7.0 REFERENCES

SWP44FL-003 Navy Fuels and Lubricants CFT Navy Coalescence Tester (NCT)

APPENDIX A

Table 1. Test Data

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	ΔP (psi)
1	390	298	51	1
2	534	165	57	3
3	378	165	76	1
4	544	108	51	1
5	375	133	63	1
6	116	80	63	1
7	257	82	63	1
8	160	97	57	1
9	464	101	82	1
10	430	84	38	1
11	665	91	51	1
12	620	101	63	1
13	1477	179	82	1
14	359	46	82	1
15	276	110	19	1
16	135	118	57	1
17	205	99	63	1
18	338	76	63	1
19	264	112	108	1
20	289	70	35	1
21	272	72	70	1
22	276	70	38	1
23	232	74	89	1
24	272	87	70	1
25	243	55	127	1
26	327	110	171	1
27	281	165	127	1
28	331	114	76	1
29	319	112	139	1
30	270	61	101	1
31	306	114	70	1
32	278	82	70	1
33	327	97	108	1
34	409	61	101	1
35	291	84	70	1
36	316	80	139	1
37	249	131	82	1
38	677	78	95	1
39	479	80	38	1
40	329	80	38	1

Table 1. Test Data (Continued)

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	ΔP (psi)
41	384	91	57	1
42	285	76	82	1
43	314	95	70	1
44	340	97	38	1
45	322	105	51	1
46	352	122	76	1
47	289	101	76	1
48	306	146	63	1
49	335	116	63	1
50	329	118	108	1
51	415	101	127	1
52	338	122	82	1
53	380	122	82	1
54	264	91	51	1
55	226	101	76	1
56	295	105	44	1
57	319	124	51	1
58	350	103	88	1
59	432	116	57	1
60	323	76	114	1
61	297	80	69	1
62	302	89	69	1
63	283	53	69	1
64	331	82	70	1
65	285	95	69	1
66	295	74	69	1
67	298	122	70	1
68	333	72	70	1
69	274	158	25	1
70	851	143	51	1
71	789	160	63	1
72	344	91	51	1
73	325	91	70	1
74	551	120	76	1
75	281	103	38	1
76	295	89	44	1
77	297	76	76	1
78	297	91	57	1
79	303	49	51	1
80	394	89	44	1

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14. ABSTRACT

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15. SUBJECT TERMS
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